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WORKING CONDITIONS AND THEIR SANITATION IN ELECTRIC WELDING OF ALUMINUM AND ALUMINUM ALLOYS

By Ye. I. Vorontsova, T. S. Karacharov, and K. P. Voshchanov

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[Following is the translation of an article by Doctor of Medical Sciences Ye. I. Vorontsova, Engineer T. S. Karacharov (Institute of Hygiene of Work and Occupational Diseases, Academy of Medical Sciences USSR), and Engineer K. P. Voshchanov (Central Experimental Welding Shops of All-Union Scientific-Research Institute of Oxy-Acetylene Welding) in Svarochnoye Proizvodstvo (Welding Industry), No 9, (1961), pages 33-36.]

At the present time, manual welding with metal-electrode and argon-shield arc welding either with a nonconsumable or consumable electrode (manual or semi-automatic) of aluminum and aluminum alloys are extensively used in industry and construction.

However, there are no data in literature as to hygienic evaluation of welding of these alloys. The appreciable prevalence of argon-shield arc and electric arc welding of aluminum and the warnings of individual organizations concerning the unfavorable working conditions of welders occupied at these jobs, render it necessary that we evaluate from the hygienic point of view these types of welding for the most extensively used alloys.

Hygienic evaluation of conditions of work was performed mainly by the method of establishing total amounts of electric-welding aerosol and gases evolved. (See Note 1)

([Note 1.] The research was conducted at the base of the Central Experimental Welding Shops of the All-Union Scientific-Research Institute of Oxy-Acetylene Welding.)

In argon-shield arc welding the following materials were studied: grade Al aluminum, and AMts, AMg6T, D20, M40, and AMg alloys which are most extensively used at the present time (Table 1). In manual welding electrodes of Experimental Welding Plant OZA-1 and OZA-2/AK were studied (Table 2).

Investigation was performed on argon-shield arc welding with consumable electrode and nonconsumable tungsten electrode. For carrying out the work a closet 0.6 x 0.7 m was built in the Central Experimental Welding Shops, with a working aperture 0.30 m^2 which was equipped with an exhaust fan. Sampling for dust and gases was done in a vertical connecting pipe with 200 mm diameter which connects the shelter with the air duct of the exhaust fan. The amount of air removed from the shelter in various experiments fluctuated from 500 to 600 m^3/hour. The rate of air movement at the place of sampling was 4.5-5.2 m/sec.

Table 1

Chemical Composition of the Electrode Wire Which Is Used in Argon-Shield Arc Welding

Chemical composition in % (according to Gost or Tu)	Alloy grades				
	AMts	AMg	AMg6	D20	M40
Principal elements					
Aluminum	Base	Base	Base	Base	Base
Manganese	1-1.6	0.15-0.40	0.5-0.8	0.4-0.8	0.9
Magnesium	-	2-2.8	5.9	-	4.5
Copper	-	-	-	8.0	4.5
Modifying additives					
Titanium	-	-	0.02-0.1	0.1-0.2	-
Impurities (not more than)					
Iron	0.7	0.4	0.4	0.3	-
Silicon	0.6	0.4	0.4	0.3	-
Copper	0.2	0.1	0.1	-	-
Magnesium	0.05	-	-	0.05	-
Zinc	0.1	-	0.2	0.1	-
Zinc plus Silicon	-	0.6	-	-	-
Other impurities	0.1	0.1	0.1	0.1	-

Table 2

Composition of Coatings of Electrodes OZA-1 and OZA-2/AK

Electrode type	Content of coating components in relation to the total weight of the coating (in %)			
	Cryolite	Potassium chloride	Sponge titanium	Flux of AF-4A type
OZA-1	25	9	1.0	65.5
OZA-2/AK	25	9	0.5	65.5

([Note] 1. Composition of Flux AF-4A (in %): NaCl 28; KCl 50; LiCl 14; NaF 8.

2. Solution of carboxymethylcellulose (12-14% for 100 parts of dry charge) was used as binder.

3. OZA-1 electrodes are made of AD-1 wire; OZA-2/AK electrodes are made of AK wire.)

Sampling was done by means of two dust tubes designed by Karacharov, which during the time of the experiment were moved along two mutually perpendicular diameters.

Air removed from the welding job by means of an industrial dust collecting fan was drawn through either cotton filters or through filters made of FPP fabric. Time of each sampling was 10-20 min in continuous welding. The quantity of wire burnt was carefully taken into account.

Table 3

Total Amount of Dust and Manganese Oxides Formed in Consumable-Electrode Welding

Type of Alloys (current)	Number of samplings	g/kg	Number of samplings	g/kg
		Argon-shield arc welding		
D20, 280 amp current	16	10.9 / 8.4 - 15.3	14	0.0925 / 0.058 - 0.106
AMts, 270 amp current	20	22.1 / 14.2 - 28.5	11	0.652 / 0.45 - 1.09
AMg6T, 270 amp current	17	52.7 / 34.1 - 83.5	16	0.233 / 0.116 - 0.425
Same, 210 amp current	10	43.26 / 33.4 - 49.5	8	0.208 / 0.102 - 0.442
AMg, 200 amp current	6	20.6 / 18.6 - 22.6	5	0.078 / 0.064 - 0.092
M40, 215 amp current	10	139 / 59 - 230	10	1.086 / 0.486 - 2.34
Aluminum, 255 amp current	12	10 / 6.1 - 13.25	-	-
		Manual arc welding		
OZA-2/AK electrodes, diameter = 5 mm, 150 amp current	9	61 / 54 - 67	-	-
OZA-1 electrodes, diameter = 5 mm, 180-200 amp current	8	38.4 / 30 - 48	-	-

([Note] The numerator depicts mean data, and the denominator depicts the maximum and minimum values.)

Welding in argon medium by consumable electrode 1.6 - 2 mm in diameter was performed by a direct 210-280 amp current with gas consumption of 13-14 l/minute by means of a semi-automatic welding machine PShPA-10.

Manual arc welding with OZA-1 and OZA-2/AK electrodes 5 mm in diameter was performed by a direct current in reversed polarity (150-200 amp). A total of about 70 experiments was carried out. The air taken from the connecting pipe was analyzed for dust, oxides, manganese, and also ozone, oxides of nitrogen, and hydrogen fluoride and chloride content.

Data obtained are adduced in Tables 3 and 4.

Table 4

Total Amount of Ozone and Oxides of Nitrogen in Consumable-Electrode Welding

Type of alloy	Welding		Oxides of nitrogen	
	Number of samplings	g/kg	Number of samplings	g/kg
		Argon-shield arc welding		
D20	6	0.108 / 0.087-0.116	5	0.935 / 0.38 - 2.3
AMg6T	12	Not detected	7	2.45 / 0.91 - 3.60
M40	3	Same	5	3.74 / 1.2 - 5.9
AMg	8	0.079 / 0.054 - 0.108	7	0.386 / 0.181 - 0.544
Al	19	0.137 / 0.103 - 0.163	5	0.90 / 0.68 - 1.1
		Manual arc welding		
OZA-2/AK Electrodes) OZA-1 Electrodes)	18	Not detected	6	4.64 / 2.42 - 9.76

([Note] In manual arc welding hydrogen fluoride is also evolved in the amount of 0.85-1.57 g/kg and hydrogen chloride in the amount of 2.86-4.4 g/kg.)

We see from Table 3 that the greatest total emission of dust in metal-arc welding in argon medium is observed in welding with electrode wires M40 (139 g/kg) and AMg6T (52.7 g/kg).

From comparison of the obtained data with the chemical composition of the wire we see that maximum liberations of electric welding aerosol are observed in welding alloys which contain magnesium.

Total amount of electric welding aerosol liberated in welding with OZA-1 and OZA-2/Ak electrodes fluctuates between 38.4 and 61 g/kg. The main portion of the dust formed in the process of welding, consists of aluminum oxides.

The total amount of manganese oxides generated also fluctuates within an appreciable range between 0.078 and 1.086 g/kg.

We see from Table 4 that evolution of ozone, according to the analysis data, is observed in welding with D20, AMg and Al wire. In welding with AMg6G and M40 wire ozone was not detected, although we cannot aver that in this instance it does not escape into the air. Evidently, detection of ozone is impeded by the presence of significant concentration of oxides of nitrogen in the air, which fact takes place in welding with AMg6T and M40 wires (2.45 - 3.74 g/kg); in welding with D20, AMg, and Al electrode wire total evolution of oxides of nitrogen was only 0.386-0.935 g/kg.

From the hygienic point of view ozone is the most significant of the gases that form in argon-shield arc welding of alloys investigated; in manual arc welding hydrogen fluoride is the most important gas.

Research on hygienic evaluation of welding with nonconsumable tungsten electrode was performed with and without use of welding filler wire. Fine aluminum plates 6 and more millimeters thick were welded with tungsten electrodes 2.5 and 5 mm in diameter with 100 and 300 amp current. Eight experiments were performed the results of which are adduced in Table 5. Inasmuch as the quantity of filler wire in this method of welding does not characterize the procedure of the process the data obtained were taken in relation to 1 hour of continuous welding and not to 1 kg of electrodes consumed.

We see from Table 5 that the total amount of dust formed in welding with nonconsumable electrode is negligible in comparison to the amount of dust formed in consumable electrode welding (see Table 3).

The control samples for establishing ozone content in the air removed showed that in nonconsumable-electrode welding in 1 hour of continuous welding 90 mg ozone is generated (when its mean concentration in the air removed is 0.00016 mg/l).

Table 6 adduces dust and gas concentration in argon-shield arc welding of various aluminum-magnesium alloys. From the data adduced therein we see that concentration of dust in the zone of welder's

Table 5

Total Amounts of Dust Formed in Nonconsumable-Electrode Welding of Al Aluminum Plates

Method of work	General dustiness	
	Number of samples	g/hour
1. Tungsten-electrode welding, electrode d = 2.5 and 5 mm, current of 100 and 300 a, no filler wire used	8	$\frac{2.81}{1.43 - 3.76}$
2. Same, with filler wire	8	$\frac{2.51}{1.38 - 5.14}$

Table 6

Concentration of Dust, Ozone, and Oxides of Nitrogen in the Zone of Welder's Breathing in Argon-Shield Arc Welding of Aluminum-Magnesium Alloys

Method of Welding	Dust		Ozone		Oxides of nitrogen	
	Number of samples	mg/m^3	Number of samples	mg/l	Number of samples	mg/l
Nonconsumable electrode welding	46	$\frac{2.3}{1.3 - 4}$	20	$\frac{0.00012}{\text{traces}-0.0002}$	12	traces
Consumable electrode welding	12	$\frac{44}{12.6 - 54.6}$	11	$\frac{0.00043}{0.0002-0.0006}$	7	traces

breathing in consumable-electrode welding is on the average 44.0 mg/m^3, whereas in nonconsumable electrode welding dust concentrations did not exceed 4.0 mg/m^3.

Welding dust is extremely fine: 99% of the particles are under 1 γ in size. Ozone concentration fluctuated from traces to 0.0006 mg/l. Oxides of nitrogen were detected only as traces.

The experiments performed on determination of total generation of dust and gases, as well as investigations in industry stress the necessity of measures to be carried out for sanitation of conditions of work.

In particular, manual arc welding and semi-automatic welding should be replaced by automatic methods. For hygienic reasons alloys which are characterized by lower generation of aerosol in welding, are most suitable to be used.

Measures for removing dust and gases formed from the production premises are of the greatest significance in sanitation of conditions of work of welders. Our research showed that in welding light-metal alloys construction of effective ventilation is compulsory.

It is expedient to situate welding jobs in isolated premises, which fact facilitates construction of the ventilation necessary and protects the principal production premises from contamination of its air medium. Ventilation in assembly-welding shops should be both local and general-exchange. Local exhaust ventilation should be accommodated either by a wide side suction or a bottom under-the-grid suction.

Foreign researchers (Frant and Venema) suggest that argon-shield arc welding be done on a special bench with a portable shelter and under-the-grid suction (Fig 1); the portable shelter, in their opinion, affords the use of ventilation in welding both small and big articles.

Volume of the air drawn off should attain 2100 m^3/hour. The interior surface of the shelter should be covered with a paint containing zinc oxide, in order to decrease reflection of ultraviolet rays.

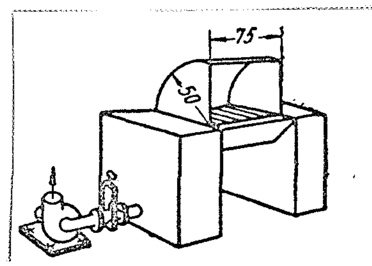

Fig. 1. Special bench for welding with portable shelter and under-the-grid suction.

A good hygienic effect can be achieved by setting up a wide side suction (Fig 2) situated over the welding bench at a distance which is most convenient for conducting the process under given conditions. In this instance the volumes of the air drawn off are determined by the rate of suction of air in the welding zone, which should not be less than 0.4-0.5 m/sec. The required rates of suction of air are determined in each specific instance with the view that the gas shield of the arc is not disturbed. For an exhaust receptacle of the size depicted in Fig 2, the effective volume of drawn-off air is 1500-2000 m^3/hour.

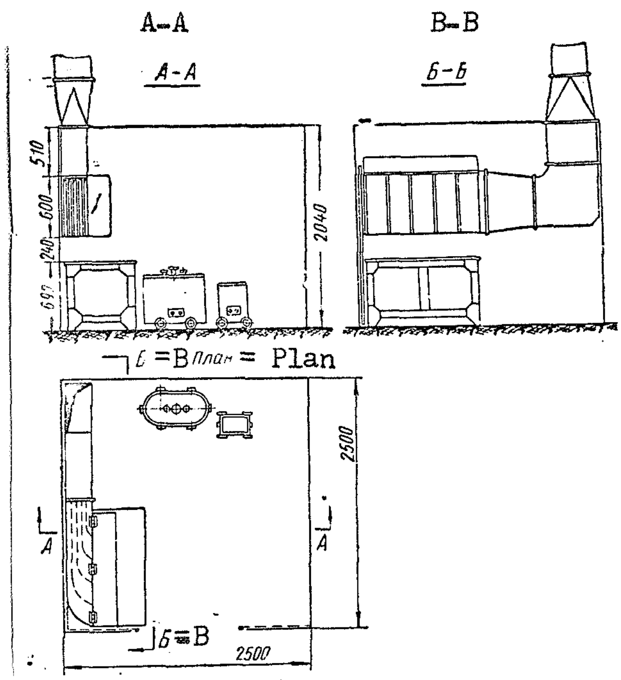

Fig 2. Layout of wide side suction.

In welding large articles special portable receptacles which are connected with the exhaust main by means of flexible sleeves, may be used.

If for any reasons it is impossible to use local suction, use of individual means of protection of respiratory organs in the form of masks and half-masks with air supply, is compulsory. Some of such devices are hose gas mask PSh-2, Averkiyev's respirator gas mask, and hose gas mask of the Central Scientific-Research Institute. Orekhovo-Zuyevo Plant "Respirator" began serial output of the automatic device ASM which is designed to protect respiratory organs of welders and painters who work in enclosed space. The automatic device (Fig 3) operates from a system with air compressed to 4-6 atm, which has been purified of oils and mechanical impurities under pressure. The mask

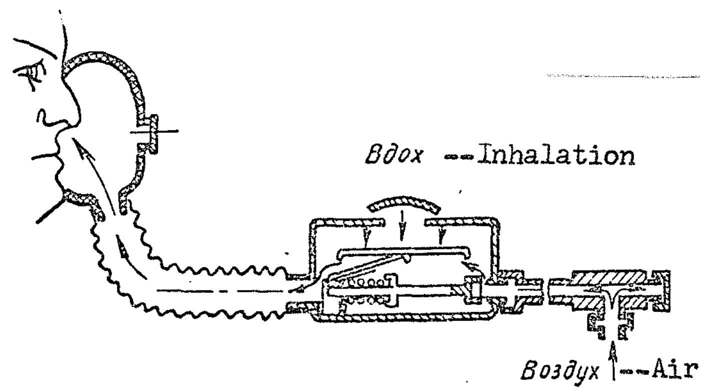

Fig 3. Automatic device ASM for protecting respiratory organs of the welder.

of this automatic device should be used in combination with hose gas masks also.

In premises where arc welding is performed, setting up general-exchange ventilation is compulsory; volumes thereof are determined in accordance with existence and effectiveness of local exhaust ventilation.

In the absence of local exhaust system volumes of general exchange ventilation are established on the basis of total evolution of arc-welding aerosol per 1 kg of wire consumed to be diluted to the level of maximum permissible concentration, which in this instance should be assumed at 2 mg/m^3.

Use of trichloroethylene and dichloroethane as dilutants for degreasing the articles welded should be avoided, because these chemicals in interaction with ozone may form phosgene, -- an extremely toxic substance of suffocating action.

In addition to dust and gases, radiation is an occupational hazard in argon-shield arc welding. A correct selection of protective light filters in accordance with the Bureau of Standards Regulation 9497-60 completely protects welders from this hazard.

Conclusions

1. In semiautomatic consumable-electrode argon-shield arc welding of aluminum alloys and in manual arc welding considerable amounts of dust are formed which attain 10.9 -139 g/kg in argon-shield arc welding depending on the composition of alloys, and 38.4-61 g/kg in manual arc welding. Presence of magnesium in alloys significantly increases dust formation. Total evolution of manganese oxides in consumable electrode welding fluctuates between 0.078 and 1.08 g/kg.

2. Of gases which evolve in the welding process, ozone and hydrogen fluoride are most noxious. In argon-shield arc welding ozone evolutions, according to average data, constitute 0.079-0.137 g/kg of the wire consumed; evolution of hydrogen fluoride in manual arc welding is, on the average, 0.85-1.57 g/kg.

3. In nonconsumable (tungsen) electrode argon-shield arc welding formation of arc-welding aerosol and manganese oxides is negligible. In this instance ozone is the principle occupational hazard.

4. Research showed that in welding aluminum and aluminum alloys it is necessary to take sanitary measures, principally for protection of respiratory organs and eyesight of the workers from the action of dust, gases, and radiation energy by setting up local and general exchange ventilation, and the welders' eyes by screens and helmets with special glasses.

5. Research should be performed on hygienic evaluation of automatic methods of welding aluminum and aluminum alloys (according to the cost of flux, etc.).

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